

WHAT IS CLAIMED IS

1. A method for forming a contact plug of a  
5 semiconductor device comprising:

forming an insulating layer on a silicon substrate;  
opening a contact hole in the insulating layer, wherein  
a portion of the silicon substrate is exposed at a bottom of  
the contact hole; and

10 selectively growing a silicon epitaxial layer in the  
contact hole, wherein the selective epitaxial layer comprises  
a single crystal silicon portion, and a polycrystalline or  
amorphous silicon portion,

15 wherein the single crystal silicon portion comprises a  
substantially conical structure, a base of which substantially  
covers the exposed portion of the silicon substrate, and

further wherein the polycrystalline or amorphous silicon  
portion fills the remainder of the contact hole.

20 2. The method for forming a contact plug of a  
semiconductor device according to claim 1:

wherein the step of selectively growing a silicon  
epitaxial layer in the contact hole further comprises an LPCVD  
process wherein a reaction gas is a gas mixture comprising MS  
25 (SiH<sub>4</sub>) and H<sub>2</sub> or a gas mixture comprising DSC (SiCl<sub>2</sub>H<sub>2</sub>) and H<sub>2</sub>  
and a dopant gas is PH<sub>3</sub>.

3. The method for forming a contact plug of a

semiconductor device according to claim 2:

wherein a flow of MS gas or DCS gas is controlled to be approximately 100 to 500 sccm and

5 a flow of H<sub>2</sub> gas is controlled to be approximately 2,000 to 20,000 sccm.

4. The method for forming a contact plug of a semiconductor device according to claim 2:

wherein a flow of PH<sub>3</sub> gas is controlled to obtain a 10 phosphorus doping concentration in the silicon epitaxial layer between approximately  $1 \times 10^{19}$  to  $10^{21}$  atoms/cc.

5. The method for forming a contact plug of a semiconductor device according to claim 1:

15 wherein the step of selectively growing the silicon epitaxial layer is conducted within a pressure range of approximately 1 to 200 Torr.

6. The method for forming a contact plug of a 20 semiconductor device according to claim 1:

wherein the step of opening a contact hole in the insulating layer further comprises;

applying a dry cleaning process to the exposed portion of the silicon substrate;

25 applying a wet cleaning process to the exposed portion of the silicon substrate; and

baking the exposed portion of the silicon substrate in H<sub>2</sub>;

these steps being completed before the step of

selectively growing a silicon epitaxial layer in the contact hole.

7. The method for forming a contact plug of a  
5 semiconductor device according to claim 6:

wherein the step of applying a dry cleaning process further comprises treating the exposed portion of the silicon substrate using a NF<sub>3</sub>/O<sub>2</sub> plasma for approximately 20 to 30 seconds.

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8. The method for forming a contact plug of a semiconductor device according to claim 6:

wherein the step of applying a wet cleaning process further comprises treating the exposed portion of the silicon substrate using a mixed solution of BOE and H<sub>2</sub>SO<sub>4</sub> for approximately 20 to 30 seconds.

9. The method for forming a contact plug of a semiconductor device according to claim 6:

20 wherein the step of baking further comprises treating the exposed portion of the silicon substrate using H<sub>2</sub> at a temperature between approximately 700 and 1,000°C for approximately 60 to 300 seconds.

25 10. The method for forming a contact plug of a semiconductor device according to claim 1:

wherein the step of selectively growing a silicon epitaxial layer further comprises

growing the single crystal silicon portion using a LPCVD

process at a temperature of approximately 600 to 700°C; and then

growing the polycrystalline or amorphous silicon portion at a temperature of approximately 550 to 650°C.

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11. The method for forming a contact plug of a semiconductor device according to claim 10:

wherein the step of selectively growing the silicon epitaxial layer further comprises a LPCVD process using a 10 reaction gas comprising a gas mixture of MS ( $\text{SiH}_4$ ) and  $\text{H}_2$  or a gas mixture of DSC ( $\text{SiCl}_2\text{H}_2$ ) and  $\text{H}_2$  and a dopant gas comprising  $\text{PH}_3$ .

12. The method for forming a contact plug of a 15 semiconductor device according to claim 11:

wherein a flow of MS gas or DCS gas is controlled to be approximately 100 to 500 sccm and

a flow of  $\text{H}_2$  gas is controlled to be approximately 2,000 to 20,000 sccm.

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13. The method for forming a contact plug of a semiconductor device according to claim 12:

wherein a flow of  $\text{PH}_3$  gas is controlled to obtain a 25 phosphorus doping concentration in the silicon epitaxial layer between approximately  $1 \times 10^{19}$  to  $10^{21}$  atoms/cc.

14. The method for forming a contact plug of a semiconductor device according to claim 10:

wherein the step of selectively growing the silicon

epitaxial layer is conducted within a pressure range of approximately 1 to 200 Torr.

15. The method for forming a contact plug of a  
5 semiconductor device according to claim 10:

wherein the single crystal silicon portion has a height of approximately 500Å.

10 16. The method for forming a contact plug of a semiconductor device according to claim 10:

wherein the step of growing the single crystal silicon portion is completed in approximately 30 to 60 seconds.

15 17. The method for forming a contact plug of a semiconductor device according to claim 10:

wherein the step of growing the polycrystalline or amorphous silicon is performed at a temperature of approximately 550 to 610°C.

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18. A method for forming a contact plug of semiconductor device comprising, in sequence, the steps of:

preparing a silicon substrate;

25 forming an insulating layer on the silicon substrate;

forming a contact hole in the insulating layer to expose a portion of the silicon substrate;

dry cleaning the exposed portion of the silicon

substrate;

wet cleaning the exposed portion of the silicon substrate;

inserting the silicon substrate into a LPCVD apparatus;

5 H<sub>2</sub> baking the exposed portion of the silicon substrate region;

selectively growing an epitaxial single crystal silicon portion on the exposed portion of the silicon substrate at a temperature of approximately 550 to 700°C;

10 selectively growing a second epitaxial silicon portion on the epitaxial single crystal silicon portion, the second epitaxial silicon portion comprising polycrystalline silicon, amorphous silicon, or a combination thereof, at a temperature of approximately 550 to 700°C, the thickness of the second 15 epitaxial silicon portion being sufficient to render the contact hole at least substantially filled; and

removing the silicon substrate from the LPCVD apparatus.

19. The method for forming a contact plug of a 20 semiconductor device according to claim 18:

wherein the step of dry cleaning the exposed portion of the silicon substrate further comprises treating the silicon substrate a NF<sub>3</sub>/O<sub>2</sub> plasma for approximately 20 to 30 seconds.

25 20. The method for forming a contact plug of a semiconductor device according to claim 18:

wherein the step of wet cleaning the exposed portion of the silicon substrate further comprises applying a mixed

solution of BOE and H<sub>2</sub>SO<sub>4</sub> to the silicon substrate for approximately 20 to 30 seconds.

21. The method for forming a contact plug of a  
5 semiconductor device according to claim 18:

wherein the step of H<sub>2</sub> baking further comprises treating the silicon substrate at a temperature of approximately 700 to 1,000°C for approximately 60 to 300 seconds.

10 22. The method for forming a contact plug of a semiconductor device according to claim 18:

wherein the epitaxial single crystal silicon portion comprises a substantially conical or pyramidal structure grown on the exposed portion of the silicon substrate; and

15 the second epitaxial silicon portion is grown on an exposed surface of the epitaxial single crystal silicon and on a sidewall of the contact hole.

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